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ABSTRACT

This paper describes a hypermedia resource, called MendelWeb that integrates elementary biology, discrete mathematics, and the history of science. MendelWeb is constructed from Gregor Menders 1865 paper, "Experiments in Plant Hybridization". An English translation of Mendel's paper, which is considered to mark the birth of classical and evolutionary genetics, is presented as an active document, with links to traditional reference material (e.g. glossaries, biographies, and the original German text) as well as images, tutorials, active commentaries, related Web sites, and animations. Users can choose to view any of several versions of the Mendel paper, each featuring different degrees of activity and annotation, and MendelWeb is designed to be accessible and useful to those running basic text browsers like Lynx, as well as full-featured browsers like Mosaic. MendelWeb, which is currently under construction at Brown University, is proposed not as an on-line textbook, but as a resource for teachers and students inside and outside traditional school environments. The links integrate elementary mathematics (i.e. probability and statistics), classical genetics, European history, and the history of early modern biology, in ways unavailable to traditional textbooks and even CD-ROM resources. MendelWeb will be valuable for teachers and students at the secondary and undergraduate levels, along with people of all ages pursuing independent studies. Finally, MendelWeb includes a series of project links, to encourage the construction of a larger web, tracing the history of genetics through the 19th, 20th, and into the 21st, centuries. MendelWeb can be accessed at http://netspace.org/. (Author/NB)

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MendelWeb: An electronic science/math/history resource for the WWW

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Abstract

This paper describes a hypermedia resource, called MendelWeb, that integrates elementary biology, discrete mathematics, and the history of science. MendelWeb is constructed from Gregor Mendel's 1865 paper, *Experiments in Plant Hybridization* . An English translation of Mendel's paper, which is considered to mark the birth of classical and evolutionary genetics, is presented as an active document, with links to traditional reference material (e.g. glossaries, biographies, and the original German text) as well as images, tutorials, active commentaries, related Web sites, and animations. Users can choose to view any of several versions of the Mendel paper, each featuring different degrees of activity and annotation, and MendelWeb is designed to be accessible and useful to those running basic text browsers like Lynx, and well as full-featured browsers like Mosaic.

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Introduction

In a recent article about the possibilities of hypertext, and the so-called "textbook of the future", the authors begin with the rather startling premise: "Textbooks. .... how we love textbooks ...."[1] This paper begins with a different, somewhat less cheerful attitude , which might be summarized by the question: "Why would we wish to transfer the problems we associate with printed textbooks, to an electronic format?" For while there are certainly wonderful, classic textbooks in nearly every field of study, as students and teachers we know that the great majority of secondary school and undergraduate textbooks are extremely disappointing, and we often use them only with the strongest disavowals. And while some of the disappointment has always to do with the particular approach and style of the author(s), often there are problems that have to do with the inherent structure of textbooks. As this paper is about an electronic resource that can be used for teaching and studying classical genetics, I begin with two of the common problems associated with even the most successful genetics textbooks.

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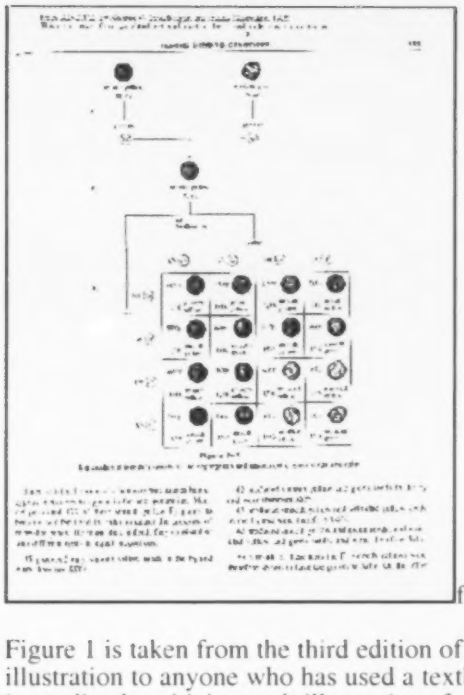

fig.1

fig.2

Figure 1 is taken from the third edition of Monroe Strickberger's *Genetics* ,[2] and will be a familiar type of illustration to anyone who has used a textbook for a course in the biological sciences. While a modern reader might immediately criticize such illustrations for not being colorful or active, there is, I think, a much deeper problem. Proposed as an "explanation" of Mendel's results, the figure on the page makes no reference to actual data; posing as a direct representation, it is rather a picture of an interpretation of the experimental results.[3] Similarly, in the text below the figure, we read that Mendel performed a particular experiment that yielded four different types of offspring, in equal proportions; yet, the statement is followed by four numbers, apparently drawn from Mendel's data, which are none of them the same as another, and no explanation is offered. The point of this example is that such descriptions and explanations gloss and even misrepresent the theories and practices of science in important respects, and textbooks (science textbooks in particular) are rather infamous for just these sorts of misrepresentations.

Figure 2 is taken from Ursala Goodenough's *Genetics* (3rd ed.),[4] and it too describes the results Mendel's experiment; specifically, the text describes the "history" of Mendel's experiments and explains the discovery of dominant and recessive characters.[5] This example is chosen for its unfortunate, and quite typical, treatment of history. Notice not only the odd collection of propositions that are assembled as a "history" of the experiments (figure 3), but also how peripheral historical considerations are made to seem to a discussion of Mendel's experiments.[6] Indeed, the stripping away of historical descriptions and considerations as a science "progresses", is part of a mythology of science promoted not only by textbooks but by professional scientists as well. And while this sort of presentation may be appropriate for those receiving professional training, for the student encountering serious science for the first time, or as part of general education, the absence of historical discussions that are meaningfully integrated into the descriptions and explanations of "the facts", is an unnecessary and grossly misleading feature of a great number of textbooks.

Here one must emphasize that both the Strickberger and Goodenough textbooks are successful, well-written works; and of course the sorts of problems identified may often be insoluble because of the realities of print, or as a consequence of a variety of competing commercial and intellectual interests. The point of the examples is simply that many of the most unfortunate aspects of printed textbooks, and science textbooks in particular, can easily be duplicated in new, electronic formats. Thus, we ought to take great care to reform not only the medium of the next generation of textbooks, but their style and content as well. Fortunately, the realities of hypermedia and active pages on the World Wide Web allow solutions to many of the problems traditionally associated with textbooks.

The Origins of MendelWeb

In 1981, a new course was offered at Columbia College, called "Theory and Practice of Science".[7] Designed primarily for first- and second-year undergraduates fulfilling their science requirements, and offered as an alternative both to "service" and traditional "science for non-scientist" courses, "Theory and Practice of Science" introduced sufficient mathematics so that original science papers could be used as the basis for study. Each of two semesters

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began with several weeks of mathematics, drawn from a variety of pure and applied topics, which were followed by a unit of science structured around a sequence of original articles; a unit in physics was built upon the discovery of nuclear fission, from Faraday to the 1939 paper by Meitner and Frisch, and a biology unit followed the discovery of the structure of DNA, from Mendel's pea plant paper of 1865 through the 1953 papers by Watson and Crick.[8]

The success of "Theory and Practice of Science", which led to a restructuring of all courses satisfying the science requirement at Columbia, was due to a number of features that were uncommon in science education. First, the course was taught by professors from different disciplines, who were encouraged to observe and participate in each other's lectures and discussions.[9] Second, the use of primary texts allowed for a classroom setting much like a seminar, and took greatest advantage of the excellent reading and analytical skills that non-scientists often bring to their courses. The opportunity to exercise these skills, to *discover* the results of particular researches rather than be told of their outcomes, and to see science as an activity embedded in history, proved an excellent motivation for students who might otherwise have been put off by the more technical material. Finally, the course integrated laboratory sessions only when those sessions were directly relevant to the papers, thus eliminating the sorts of "cookbook" laboratory work that is too often a part of introductory science courses. In the absence of significant labs, working with the papers themselves proved to be a remarkably valuable "hands-on" experience for a large number of students.

Unfortunately, there were also a number of problems with "Theory and Practice of Science". First, and perhaps foremost, the time constraints of a 4 hour/week course stifled the interdisciplinary exploration inspired by the primary texts, and as each science unit was designed to cover numerous discoveries, there was too little time to take advantage of the different sorts of questions motivated by each paper. Second, during the first few years the course was offered, students received copies of the papers, along with professor's notes, and separate problem sets. But when a textbook was written, and combined these resources, many students lost interest in wrestling with the original articles and relied exclusively on the accompanying narrative. Conversely, when new instructors came into the course, they frequently complained of the style and perspectives of the narrative, and sometimes preferred a different sequence of papers. In addition, the absence of regular laboratory sessions, for performing experiments described by or related to the papers, often placed a limit on students' understanding of the material. Finally, as both the authors of the text, and the instructors, were primarily scientists, the sorts of historical, and social questions which arose from close readings of the original papers were too rarely pursued.[10]

MendelWeb, then, has been designed as a set of hypermedia tools for students and teachers interested in the approach to scientific literacy and education embodied in curriculum of "Theory and Practice of Science," but who desire varying degrees and directions of interpretation and commentary to accompany primary texts. Although much has been written about the supposed "non-linearity" of hypertext, it is rather the ability of hypertext to give users the feeling of studying and learning in a transfinite environment, that makes it appropriate for MendelWeb. Similarly, the realities of the World Wide Web should allow designers of educational resources not to disappoint the expectations inspired by such a feeling.

The Structure of MendelWeb

The focus of MendelWeb is the text of Gregor Mendel's 1865 paper, "Versuche über Pflanzen-Hybriden", and its English translation "Experiments in Plant Hybridization. Although users may view and download "clean" versions of these papers in a number of formats, MendelWeb contains a heavily annotated English version, in which words, phrases and data are linked to glossaries, biographies, and short essays explaining and illustrating many of the objects and activities described in the paper. Figure 4 shows the first page of the paper as it appears in Mosaic, while figure 5 shows the result of clicking on the word "flower", when it first appears in the text.[11]

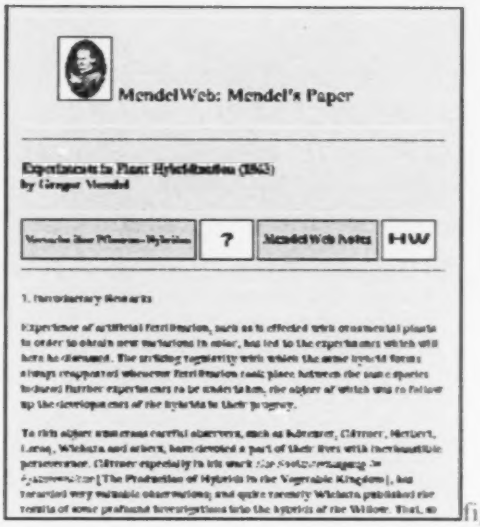

fig.4

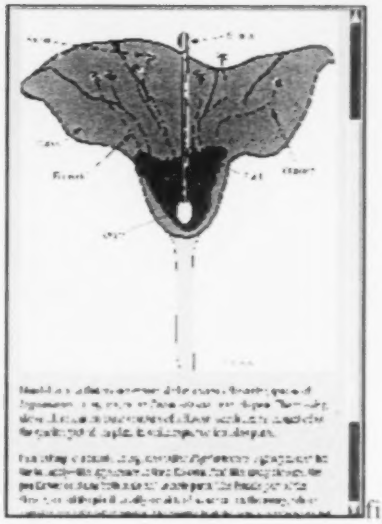

fig.5

Several features of the annotated text make it suitable for coursework as well as independent study. The eleven sections of Mendel's paper are bounded by a series of buttons linking the reader with four sorts of resources:

- The original German text of Mendel's paper. As the translation contained in MendelWeb is a slightly modified version of Bateson [1909], and there exist other recommended translations[12] many users will wish to examine Mendel's own expressions.

- A set of discussion questions specific to each section of the paper. These questions are meant to inspire further researches and discussions. We imagine that various groups and individuals using MendelWeb will wish to discuss these questions with one another, and one hopes there will be a need to link these sections both to temporary Internet lists and more creative settings (e.g. MOOs).

- A set of notes devoted to scholarly material and controversies concerning each section of the paper. It is among these notes, for example, that the user will find the excerpts from, explanations of, and references to, the various claims and debates concerning the legitimacy of Mendel's data.[13]

- A brief homework set for each section of the paper, designed as an html form.[14] The problems and exercises vary in format and are designed for a variety of abilities; furthermore, these sets can be sent for comments and/or corrections either to MendelWeb or to local sites.

In addition to the relatively static and self-contained core thus far described, the various texts and images in MendelWeb will link to a several kinds of active pages, which will themselves link to a variety of sites and documents on the World Wide Web:

- Introductory tutorials on a variety of subjects, from elementary probability and statistics, to the structure and significance of the Hapsburg Empire in the middle and late 19th century.[15]

- Active essays connecting Mendel's work with later developments and works. Thus one will find pages devoted to the "discovery" of Mendel's paper in 1900, to R.C. Punnett's *Mendelism* (1911) and G.H. Hardy's "Mendelian Proportions in a Mixed Population" (1908), as well as the chromosome interpretation of Mendel's results.

- Graphical illustrations and animations of the experiments described in Mendel's paper. Following van Dam's notion of "interactive illustrations"[16], interactive simulations of these experiments will be developed, as the ability to use such resources on the World Wide Web becomes available.

- Commentaries and appreciations by renowned scientists, historians, and writers concerning the significance of Mendel's work.

A final feature of MendelWeb is a series of links to sites and pages that inform, and are informed by, the study of Mendel's paper. Predictably, these include virtual libraries of plant science, genetics and molecular genetics, the history of science, and European history, along with sites in the Czech Republic as they become available. Perhaps

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the most important link will be to sites where Mendel's experiments are currently being repeated, and the data from those experiments are being posted. It is this final link which will make MendelWeb a truly active learning environment.[17]

Conclusion

MendelWeb is designed as a perpetual work in progress, and is meant to encourage the development of a variety of dynamic educational resources for the Web, centered around significant texts. Whereas many printed textbooks become quickly dated, and cannot satisfy large student or teacher populations because they embody an extremely weak sense of user option, electronic "sourcebooks" on the World Wide Web can contribute to a wide variety of learning environments by functioning simultaneously as archives, active databases, dynamic interactive textbooks, and sources of contemporary writing. MendelWeb is an attempt to provide such a resource.[18]

Notes

[1]Cunningham et al [1993], p.19.
[2] Strickberger [1985], p. 115.
[3] Furthermore, the text fails to describe this sort of display as a Punnett Square, and thus ignores the issue of how Mendel's results were received and reinterpreted in works like Punnett [1911] and Bateson [1909].
[4] Goodenough [1984], pps. 154-5.
[5] And here one should applaud the author for presenting Mendel's numbers *before* offering an explanation for them.
[6] Indeed, in the previous edition of Goodenough's book, the same text was confined to a "Box", which was not part of the main text at all (see Goodenough [1978], p. 89).
[7]Science C1001-2, Columbia College, Columbia University, New York NY 10027. The course was first designed and taught by: Herbert Goldstein, Professor of Nuclear Science and Engineering, and author of *Classical Mechanics* (Addison Wesley, 1950 [2nd edition, 1980]); Jonathan L. Gross, Professor of Mathematics, Statistics and Computer Science; and Robert E. Pollack, Professor of Biological Sciences. I was a student in the course during the 1981-2 year, and my involvement with the teaching and organization of the course, as well as the writing of a course textbook began in 1984.
[8]Information about the course, including syllabi and course materials, are available from the author.
[9] Such an arrangement would not have been possible without the generous support the course received from Exxon, the Mellon Foundation, the Abe Wouk Foundation, and Columbia University. Nor would it have been possible, I think, without the enthusiastic leadership the College enjoyed during the Deanship of Robert E. Pollack.
[10]The fact that the History of Science was under-represented in the Columbia faculty made the choice of instructors more narrow than it might have been desirable. When historians and philosophers of science have taught the course, historical issues have been raised and developed more often, and with notable success.
[11]Although pieces of MendelWeb are designed to take advantage of the most sophisticated graphical browers, the basic contents are texts accessible even to users confined to a VT100, or a functional equivalent. The current state of technology in U.S. public schools makes this the only reasonable design decision, at least at present, if the goal is to create a widely usable public resource.
[12] e.g. the translation by Sherwood in Stern and Sherwood [1966]. MendelWeb is based on the Bateson translation, primarily because it is in the public domain.
[13] The MendelWeb Notes will also be linked to a variety of tutorials and animations, described below, but users will also be able to access those features without linking to the Notes.
[14] One of the most exciting features of large networks as *teaching* resources is the possibility they offer for producing and maintaining enormous databases of worked exercises and problems, that could be utilized and revised by teachers and students all over the world.
[15] The tutorials in MendelWeb are designed as introductions, sufficient for the purposes of reading Mendel's paper, but which may be fruitfully continued at other sites. Thus, for example, the statistics tutorial will discuss averages, the elementary concepts of discrete probability, the idea of a statistical distribution, and the meaning and use of the standard deviation. It is hoped that more advanced material will be available on the Web for the user who wishes to pursue these studies.
[16] See e.g. Zeleznick et al [1991].
[17]The author would be grateful to hear from any institutions or individuals interested in performing Mendel's pea plant experiments, or from anyone currently performing them; if my own, less active, resources permit, I will be happy to supply the peas.

[18]For their encouragement and tolerance concerning this project, the author wishes to thank Leon N. Cooper and the members of the Institute for Brain and Neural Systems, Andy van Dam, John F. Hughes, and Lee Silverman (at Netspace).

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